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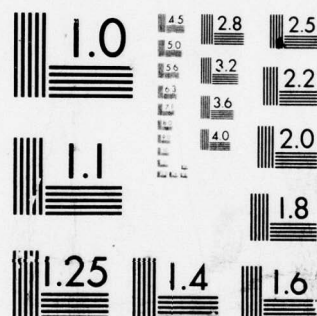
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MICROCOPY RESOLUTION TEST CHART
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COLUMBIA UNIVERSITY
HUDSON LABORATORIES
CONTRACT Nonr-266(84)

Hudson Laboratories ✓
of
Columbia University
Dobbs Ferry, New York

①

Robert A. Froesch
Director

⑨ Technical Memorandum No. 66

⑥ EXPLOSIVE SOUND SIGNALS AND SYSTEMS FOR THEIR USE.

by

⑩ Thomas G. Farrell

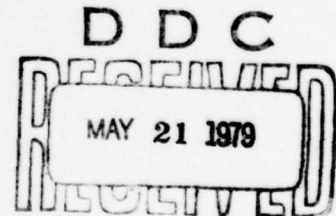
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⑪ 28 June 1963

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Based on the work performed in the recent past and what is now in progress at the lab in connection with the use of explosives for under-water sound signals, it is felt that a digest of the systems and explosive tools now available should be made known to the scientific staff. The final determination of a choice can, for any experiment, be better arrived at after weighing the factors and matching mandatory and desirable requirements in the design of an experiment with what any system or tool can supply. Approximate or relative costs in the way of material as well as pre-trip and ship time required for each type of shooting are outlined for purposes of making known what effect a choice will have on the overall experiment.

Standard Point Source Signals

<u>Name</u>	<u>Weight</u>	<u>Explosive</u>	<u>Unit Cost</u>
CAP	13.5 grain*	PETN	\$0.05
WW Booster	285 grain	193 - RDX	\$0.55
1/2 lb. chg.	1/2 lb.	TNT	Govt Furnished
2 1/2 lb. chg.	2 1/2 lb.	Tetrytol	Govt Furnished

Non-Standard Point Signals (Tests have been performed only on feasibility basis)

<u>Name</u>	<u>Weight</u>	<u>Explosive</u>	<u>Unit Cost</u>
Percussion - Primer	1/2 grain	Smokeless	
Smokeless Powder Loaded Cap	1 to 20 grain	Black Powder	\$0.01
		" " "	\$0.05
Primacord (ordinarily used in long length but may be cut to short pieces)	25 grain/ft. 60 grain/ft. 400 grain/ft.	PETN	see primacord charges

*7000 grain = 1 lb.

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Pulsed Charges (Tests have been performed only on feasibility basis)

Pulsed charges are long lengths of safety fuse (30 or 40 grain black powder per foot) with soft copper sleeves crimped at intervals to give periodic pulses at the points where the powder train in the fuse is confined. Since the burning rate of the safety fuse powder is a non-linear function of depth, the acoustical power output of the non-rupturing sleeved section can best be arrived at empirically once the depth that one would want to use such a device at is determined. Non-depth sensitive sound signals can be made by the proper selection of charge. In principle, these devices are similar to the commercial "ping" charge referenced in my memo and accompanying literature of January, 1963.

Primacord Charges

Primacord has been successfully used in a number of recent experiments and tests in three different grain loadings and for a number of purposes. Depths have been from shallow shots -- 40 ft. to 14,000 ft. deep shots. Shot geometry has consisted of (1) Straight 20 ft. line charges top fired (they can be center, bottom, or simultaneously end fired). (2) Lumped 2 1/2 lb. charges, spaced up to 10 ft. apart (2 msec water path) explosively connected by 21 ft. of primacord to give another 1 msec delay. Variations of the sizes and geometry can be made to give different delays or different bubble pulse frequencies. A subsequent approach using sympathetic detonation has proved successful with considerable gain in packaging simplification. (3) Spiral charges with "fast" lead angles on small diameter mandrels to give better horizontal directional quality or less "off vertical" lean to the shock front than a straight line charge. (4) Spiral charges with "slow" lead angles on 4 in to 10 in. diameter mandrels to give a dominant frequency which is a function of detonating rate and spiral geometry (8 in. diameter gives about 10 kc). Smaller mandrels will give higher dominant frequency, and large

mandrels will give lower frequencies. The length of the mandrel and relative geometry of charge to hydrophone will give predicable apparent frequency varying from the true frequency. Signatures can be applied to the sound sources for coding or other purposes by varying the diameter of mandrel, the pitch of primacord helix, or the grain loading for various lengths of primacord. The change in the physical variables would be reflected acoustically in larger or smaller amplitudes of the shock pulse, different dominant frequencies and delays between spikes in the range of fractions of or multiples of milliseconds.

A picture of a typical primacord spiral charge is shown in Figure 1. The mandrel consisted of a readily available 8 in. diameter aluminum can weighted at the bottom with lead. The charge consisted of 44 1/2 ft. of 60 grain/ft. PETN primacord wound in a spiral on the mandrel and initiated at the top with a 10,000 ft. or 14,000 ft. pressure detonator. This loading was to give the equivalent explosive of a standard 1/2 lb. TNT block with WW booster. An oscillogram of the direct arrival at a surface hydrophone vertically above the charge is shown in Figure 2. The 2 1/2 ft. vertical distance between the top turn and the bottom turn in a top fired charge gives an extra 0.5 msec time to the basic 2.1 msec duration pulse when observed by the surface hydrophone vertically above. This geometry also gives an apparent dominant frequency lower than would be seen by a hydrophone placed directly horizontally away from the charge. For comparison with a point source, a typical oscillogram of a 1/2 lb. TNT block with a WW booster at the same depth is shown in Figure 3.

Although primarily considered for active sonar systems, the following characteristics of line and spiral charges may be of interest as useful tools in basic sound studies: (1) Strong directional qualities horizontally compared to vertically. (2) Production of decreased bottom reverberations as compared to

equivalent point charges. (3) Ease of identification of characteristic shock pulse at receiver, even after reflection off a fair reflector as compared with a comparable point charge. (4) Simplicity of construction lends itself to shipboard variability of acoustical signal upon examination of oscillograms of trial shots. (With a Tektronix scope having 4-channel storage capacity, characteristics such as shock pulse, bubble pulse, surface and bottom reflections can be studied simultaneously from the same or successive shots before deciding on final explosive geometry). Raw data, at this point unanalyzed, in the form of oscillograms and tape recordings from a January trip exist at the lab for a variety of line and spiral charges. The classified reports in the library give some of the acoustical data gathered by others using line charges and other non-point charges.

The cost of making primacord explosive sound sources to suit various experimental needs is comparatively small. 25 grain/ft. costs \$0.026/ft.; 60 grain/ft. costs \$0.043/ft.; 400 grain/ft. costs \$0.157/ft. The mandrel upon which the primacord is wound consists of thin wall tubing which can be obtained as a surplus item in a variety of diameters or bought for less than \$0.75 per foot in the larger diameters. Lead for nose weights is surplus.

Systems

The two basic methods of initiation for any of the foregoing types of charges are electric and non-electric. Non-electric can be subdivided into safety fuse firing and pressure detonation.

Electric

Until recently at the lab, electric firing was the sole means of meeting a number of experimental design requirements. In some instances where the number of shots required is not too many and the particular experiment

will have many mandatory rather than mere desirable requirements, electrical shooting will still do the best job. Some of the requirements for which electrical shooting has been selected in the past are:

"On Demand" Firing - This requirement comes about due to (1) a need to synchronize shot time with the readiness of the distant receiving station's recording equipment; (2) a need to have knowledge of "shot instant" for purposes of transmitting absolute shot time to receiving stations so they can check travel time; (3) simplification of data analysis during programmed shot pattern.

Precision Geometry - This requirement is called for in some experiments where the relationship of shot to one or more hydrophones must be controlled precisely. Depending again on the particular experiment, the precision geometry may vary from simple precision of depth of shot to three dimensional precision relative to a drifting or anchored ship or even a fixed distant receiver or reflector.

The vertical spacing of the charges is determined by a number of factors. Sympathetic detonation of charges puts one limit on how close the charges can be. This in turn depends on the charge size, shock sensitivity of the particular electric cap used in the cap well of the safe charge, depth of the charges, and, to a lesser degree, orientation of the axis of the first charge to the second cap subjected to the shock.

The horizontal distance off the vertical combined strain-shot cable is mostly a cable safety consideration, although strings have been designed and used where no horizontal offset existed. In those cases, the rig was such that the sequential firing from the bottom up allowed the severing of expendable

cable without prejudice to the rest of the experiment. The tests and empirical data concerning sympathetic detonation are given in Hudson Laboratories Technical Memorandum No. 61 by H. Beck and R. Rico. Unless one is resigned to using standard high pressure caps with their known shortcomings concerning "true shot instant", the operational use of a seismic cap with a reliable "true shot instant" will have to be preceded by a few simple sympathetic detonation tests.

Non-Electric

Safety Fuse - Until recently at the lab, safety fuse initiation as a firing system had been called for when the experiment required no sophistication as regards shot instant or preciseness of geometry. It also met a requirement of mass shooting, that is, shallow shots at short intervals over a long period of time. Work over the past year has permitted us to extend fuse firing beyond its original primitive uses with some important advantages concerning the overall choice of an explosive system for a number of experiments.

A few of the advantages associated with free fall fused shots are listed below:

- (1) Successful firing to 2200 ft. It is anticipated with the simple techniques and work now in progress that sound channel depths are easily attainable.
- (2) Precision depth firing at all depths where fuse firing would be used. The precision of depth based on recent work has been in the order of ≤ 4 percent mean deviation for a number of depths with some depth series giving ≤ 2 percent.

(3) High degree of precision of descent time. The precision of overall descent time which combines with precise fuse burning rate to give precise depth has the added advantage of shipboard recording technique simplification. Anticipation time of direct arrival is cut down to a minimum.

(4) Shipboard variability of the desired depth of a shot series. Should a particular experiment require a last minute change in depth or progressively deeper sound signals over any given period of time, the SSOB on a receiving ship in a two-ship operation has merely to notify the senior shooter. Trimming the fuse will change the mean depth of a series a predictable amount within narrow limits.

A more sophisticated system of controlled fuse firing has been developed for a particular precision geometry experiment where a few hundred charges of various sizes were involved. As contrasted to the free fall fuse firing described above, this system consisted essentially of sliding shots from cap size to 5 lb. size down a three conductor armored cable to a stop at predetermined depths from 100 ft. to 1500 ft. A layout of the system is shown in Figure 4. More details of this system are given in Hudson Laboratories Technical Report No. 100 by T. Farrell. The use of a hydrophone preamp 10 to 20 ft. below the stop while designed to meet another experimental requirement, presented other shipboard and post-trip analysis advantages. Among these were the following:

(1) Anticipation time for Visicorder or other high speed recording minimized due to exact knowledge through hydrophone of when lead slider has hit the stop and predictable time delay before shot goes off.

- (2) A post-factum knowledge of the "shot instant" due to the short water path from explosive shock to hydrophone. While not quite as desirable as "on demand" firing for some experiments, the analysis of why one has a mandatory requirement of a "true shot instant", electrically, rather than acoustically, should be thorough before picking a system.
- (3) Post-trip analysis time, equipment, and personnel are free from the burden of determining shot depth of a long firing sequence as in free fall shot work.
- (4) The statistical advantage of a multiplicity of precise shot data at 3 to 5 minute intervals over a long period of time is obvious when compared to an electrically fired string's limitation of 10 shots per string.
- (5) With calibrated charges, complete receiving system calibration from charge to hydrophone through preamp, cable, and shipboard electronics can be carried out in the beginning, during, and end of each shot run.
- (6) Capabilities of slide shots to 10,000 ft. are within range by use of the simple devices, plumbing, and techniques now developed. Deep shots (beyond 2200 ft.) would be more economically set off by a combination of pressure primer (the precise section of Hudson Laboratories Pressure Detonator without the explosive section) and a length of safety fuse to permit the charge to reach the depth stop after the pressure primer lights the fuse.

A variation of the slide shot system using a 1/4 in. wire rope and a surface hydrophone has been used for a comparative study of different explosives. A scope-camera system was used for recording direct arrival and bubble pulse period as well as continuous tape recording. Further analysis is required on this data along with the data of the deep pressure detonated spiral, linear, and point charges from the same trip.

Pressure Detonation - Pressure detonation completes the picture of what is available in methods of initiation. Over a period of a year, the detonators have been used operationally in three major experiments in large quantities for four different depths. Depth and other data have therefore become available in usable statistical quantities to permit saying that reliability of 98 percent can be expected, and standard depth deviation of 2 to 3 percent can be expected up to 7200 ft. In smaller quantities at greater depths, 1 percent can be attained as would be expected from analysis of the design. Uniformity of descent rates with standard deviations of 1.5 percent of 11 fps mean have been attained. Improvement in this is expected on any future trip when the improved and precise lead pouring procedure is used along with more uniform packaging techniques at sea.

It should be noted that while pressure detonators will not be made up for shallower depths than 2500 ft., the pressure primer can be and has, when used with safety fuse between it and a non-electric cap. Bottom firing at any depths or firing off the bottom any given distance can easily be attained should an experiment prefer using the ocean bottom as a reference rather than the surface.

While some of the tools and systems might sound too sophisticated, in actuality much effort has been put into methods simplification and safety.

The use of non-electrical shooting where feasible is recognized as having tremendous safety advantages over electrical shooting. It is common knowledge to those who have been involved in both types of shooting that a comparison favors the non-electric when the costs in dollars, lead time, pre-trip preparation, shipboard rigging, tests, and safety procedures are all considered.

Acknowledgments

Mr. Jason Taylor and the shooters participating in the various tests and experiments involved contributed much to success of the work carried out thus far. Their cooperation and assistance are gratefully acknowledged.

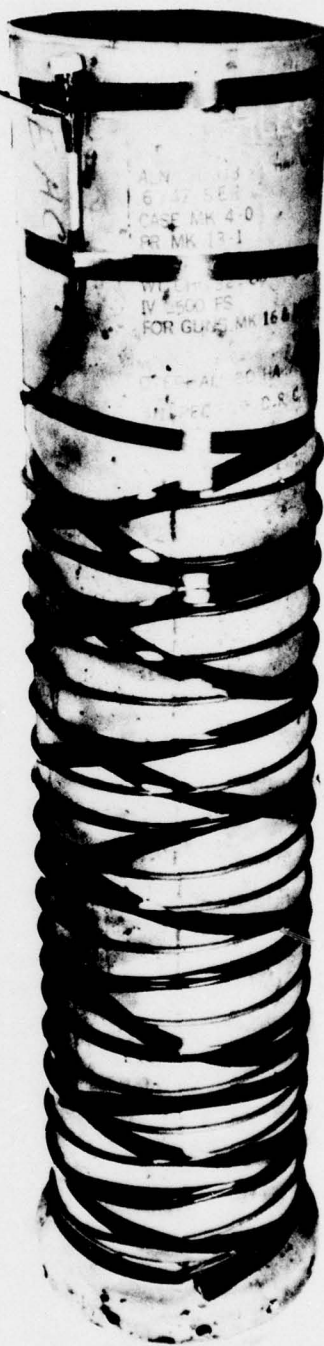
PRESSURE DETONATOR

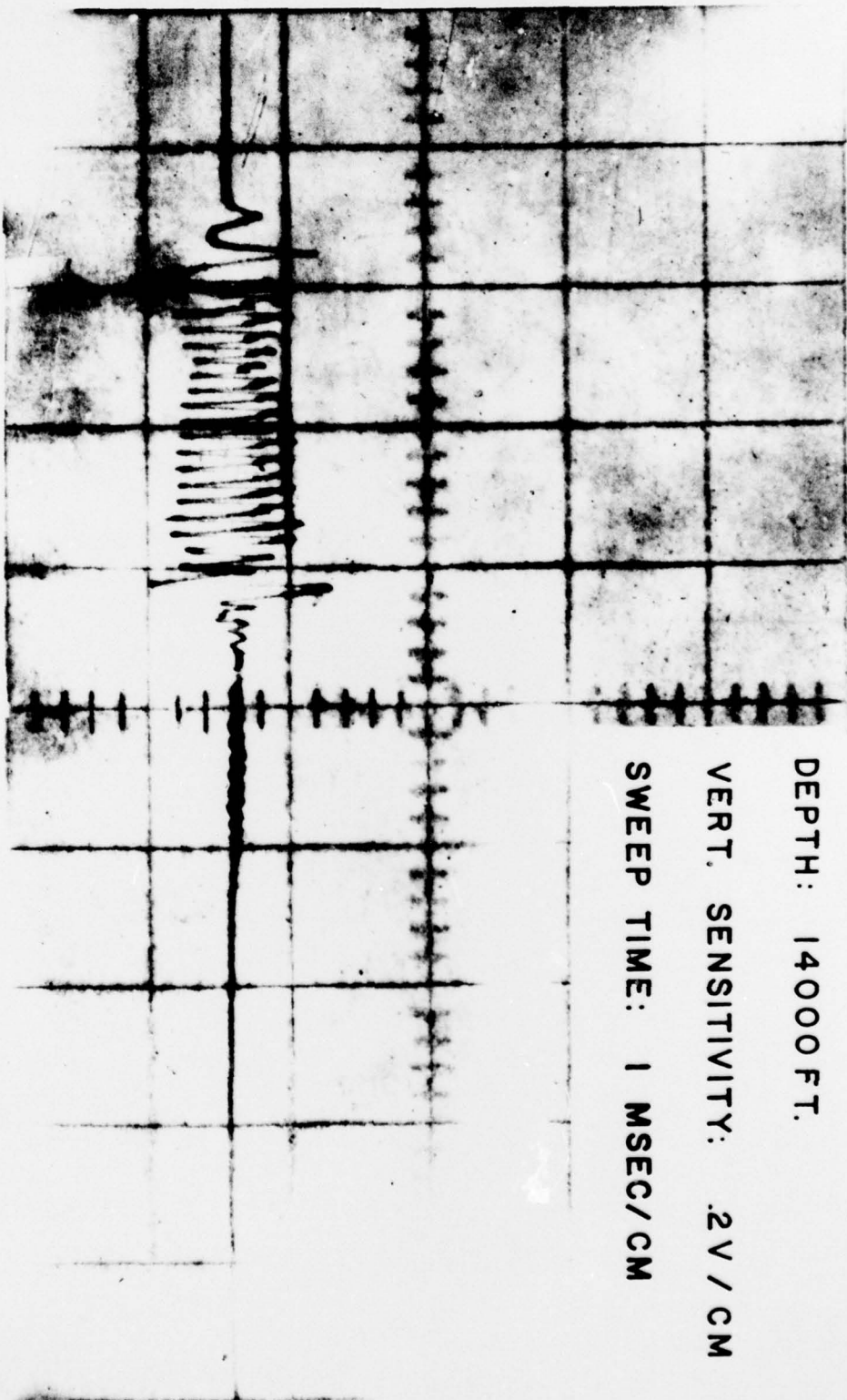
8" DIA. MANDREL

44½ FT. OF
60 GRAIN / FT.
PRIMACORD

SPIRAL PRIMACORD CHARGE
(½ LB. TNT EQUIVALENT)

FIG. 1

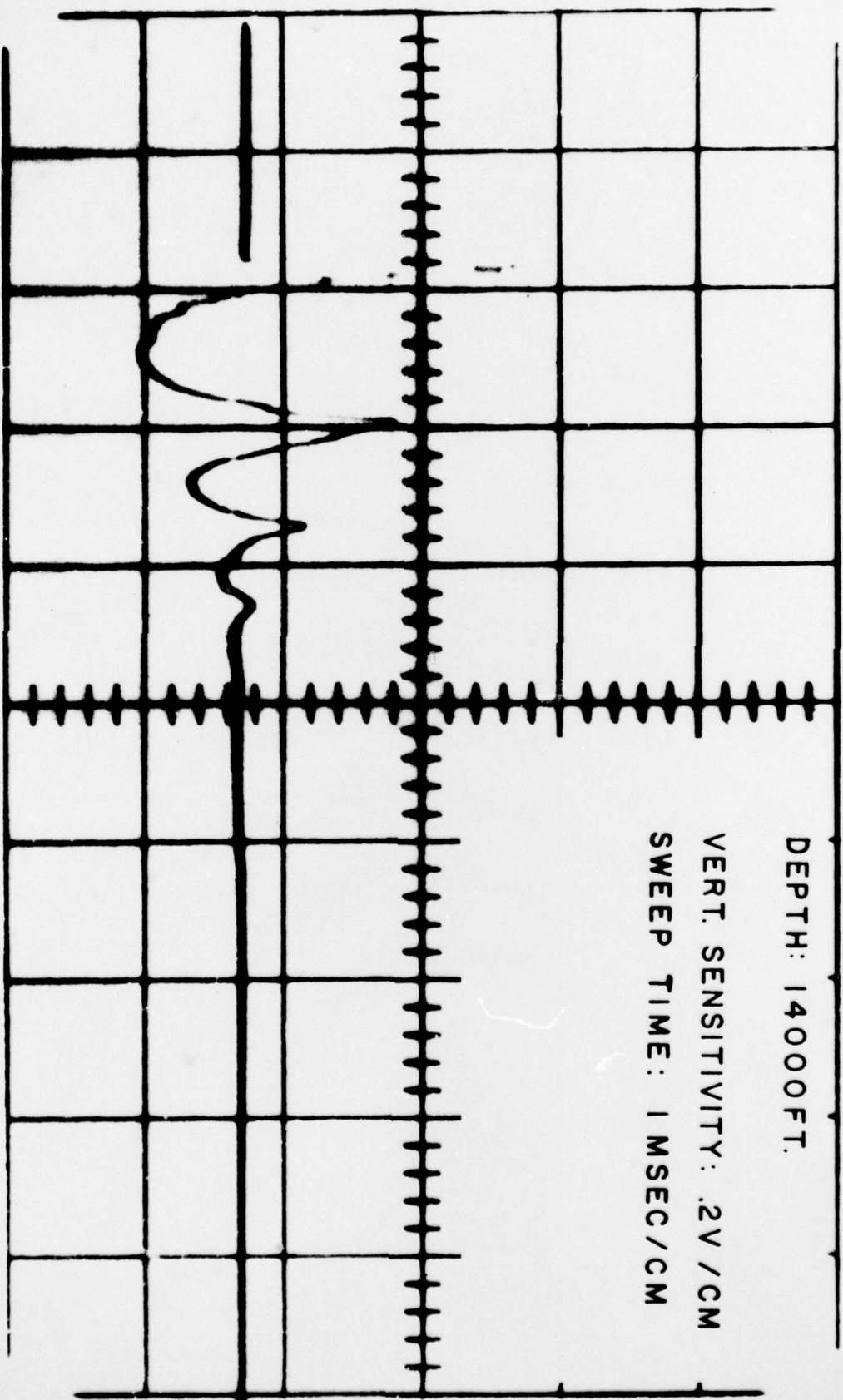




DIRECT ARRIVAL OSCILOGRAM OF SPIRAL PRIMACORD CHARGE
($\frac{1}{2}$ LB. TNT EQUIVALENT)

FIG. 2

DEPTH: 14000 FT.
VERT. SENSITIVITY: .2V / CM
SWEEP TIME: 1 MSEC / CM



DIRECT ARRIVAL OSCILLOGRAM OF $\frac{1}{2}$ LB. TNT CHARGE

FIG. 3

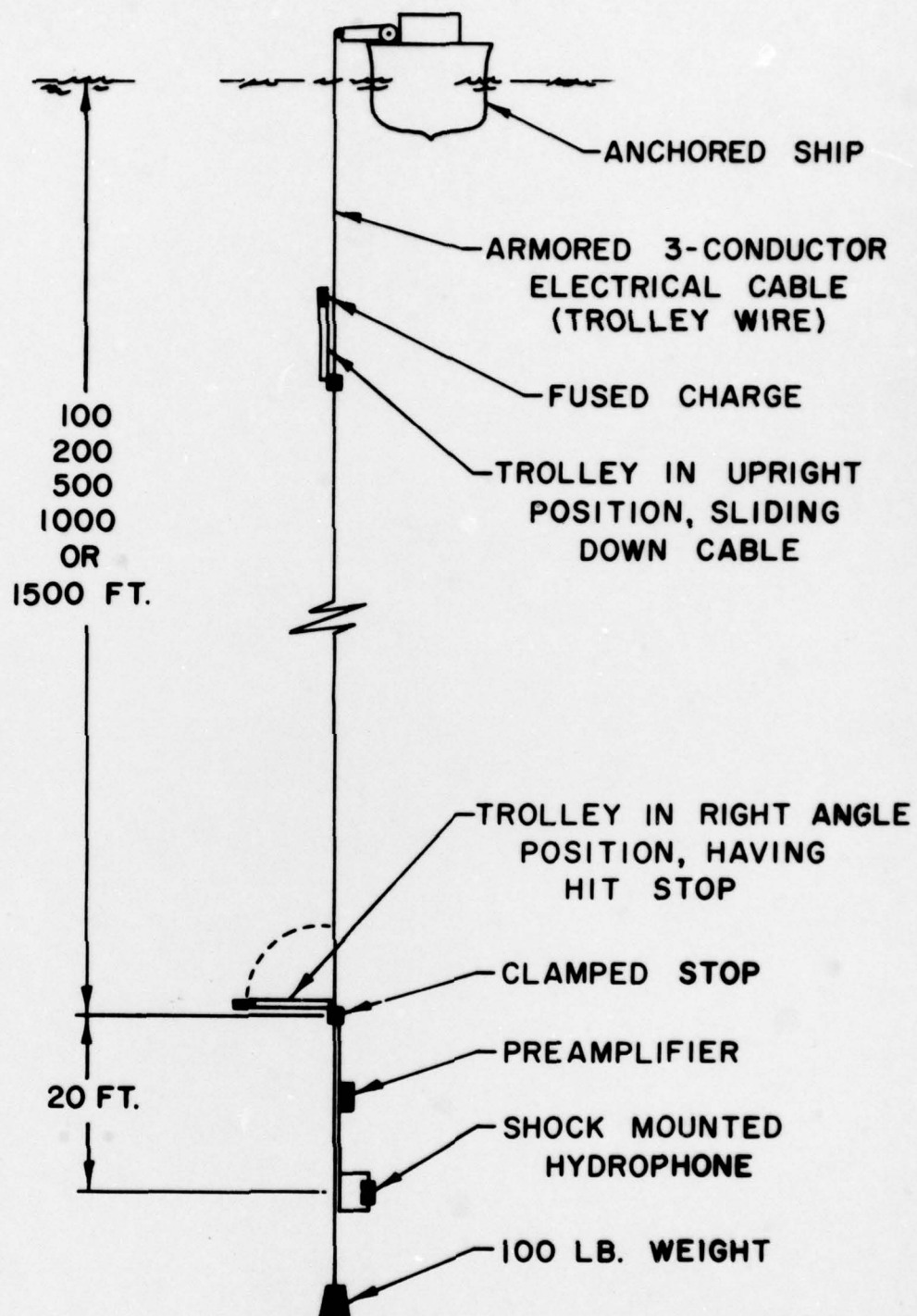


FIG. 4

LAYOUT OF SLIDE SHOT SYSTEM